

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
14 June 2001 (14.06.2001)

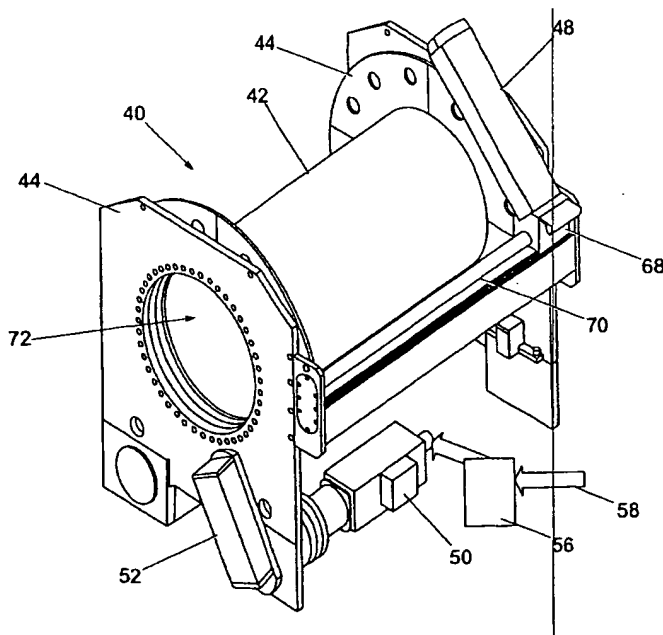
PCT

(10) International Publication Number  
**WO 01/42126 A1**

- (51) International Patent Classification<sup>7</sup>: **B66D 1/52**,  
1/50, 1/38
- (21) International Application Number: **PCT/GB00/04687**
- (22) International Filing Date: 8 December 2000 (08.12.2000)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
9929102.3 10 December 1999 (10.12.1999) GB
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- (81) Designated States (national): AE, AL, AM, AT, AU, AZ,  
BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK,  
DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL,  
IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU,  
LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT,  
RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA,  
UG, US, UZ, VN, YU, ZA, ZW.
- (84) Designated States (regional): ARIPO patent (GH, GM,  
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian  
patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European  
patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE,  
IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF,  
CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- Published:  
— With international search report.

[Continued on next page]

(54) Title: MARINE HEAVE COMPENSATING DEVICE AND WINCH DRIVE



(57) Abstract: A winch for use in a heave compensation system has a winch drum (42) driven by an AC asynchronous motor (50) via a gearbox (52). The motor (50) is controlled by a variable speed control (58) as a function of heave speed. The motor (50) and its drive train, and the winch (42), are chosen to have low inertia. The winch pays out and reels in to compensate for heave substantially instantaneously, without the need for prediction of wave patterns.

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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

1           MARINE HEAVE COMPENSATING DEVICE AND WINCH DRIVE

2

3   This invention relates to reeling and winch systems, and  
4   in particular to systems for use in maritime  
5   applications.

6

7   Typically, a maritime reeling system is mounted on a  
8   vessel to control a cable from which an article is  
9   suspended in the water from the vessel, either over the  
10   side or through a moonpool or the like. The vessel may  
11   be a ship, semi-submersible rig, oil platform or other  
12   floating vessel. The suspended article may be, for  
13   example, drilling equipment, test equipment, or an  
14   inspection chamber. In many applications of this nature,  
15   it is necessary for the suspended article to be held at a  
16   substantially fixed location, for instance to avoid  
17   damage to drilling equipment. In other situations it is  
18   important to maintain constant tension but not  
19   necessarily support a load, for example in handling  
20   tethers or umbilicals for remotely operated vehicles

1 (ROVs) and diving bells or the like. The former type of  
2 situation is commonly called "winching" and the latter  
3 "reeling", but the term "reeling" is used herein to  
4 encompass both.

5

6 In all of these situations, wave motion will cause the  
7 vessel to move up and down ("heave"), so that  
8 arrangements have been used to provide heave compensation  
9 in reeling systems.

10

11 Many prior art heave compensation systems use pneumatic  
12 or hydraulic control systems to drive a winch, there  
13 being an arrangement for recording the recent history of  
14 heave movement to provide a prediction of future  
15 movement, thereby allowing the winch to be controlled to  
16 pay out or reel in cable in an attempt to compensate  
17 future heave. However, such systems have limited  
18 usefulness owing to the non-uniformity of real life wave  
19 patterns. Also, the compressibility of the working fluid  
20 in pneumatic and hydraulic systems inevitably introduces  
21 time lags.

22

23 It is also known to use electrically powered winches  
24 controlled by electric systems. Hitherto, such winches  
25 have mostly been powered by DC motors because of the  
26 speed/torque characteristics of such motors, particularly  
27 the provision of high torque at low speed, but the use of  
28 AC motors is also known.

29

30 The commonest system is to use a single DC motor which is  
31 controlled to follow a desired torque. This leads to a  
32 phase lag between torque and speed, and hence between the  
33 input command signal and speed, which phase lag can only

1 be accommodated by the use of predictive controls.

2

3 It is also known to use two DC motors operating via a  
4 common mechanical drive system. One of the motors is a  
5 low speed, high torque motor and the other a low torque,  
6 high speed motor. The first motor is used for the main  
7 raising and lowering functions, and the second motor to  
8 provide relatively rapid heave compensation motion.  
9 However, this approach substantially increases weight,  
10 bulk and complexity.

11

12 In prior art heave compensation systems using AC motors,  
13 the motor has been controlled in terms of torque and, as  
14 with systems using a single DC motor, this leads to a  
15 phase lag between the input control signal and the speed  
16 of the motor.

17

18 This may be further explained with reference to Fig 1,  
19 which illustrates the response of a prior art system  
20 using a winch driven by a high torque, low speed electric  
21 motor, either DC or AC. Since such a motor has low speed  
22 and low acceleration, the control input 28 is a torque  
23 demand signal. The motor torque 30 follows the control  
24 input closely but, because of the inherent  
25 characteristics of the motor, is rough (jerky). The  
26 motor speed 32 then follows as a function of the motor  
27 torque 30, with a phase lag, and also with a rough form.  
28 There is thus a phase lag in the heave compensation  
29 itself, and the jerkiness of the motion is detrimental to  
30 the fatigue life of the system.

31

32 Moreover, in prior art systems whether using hydraulic,  
33 DC or AC motors, the motor has been chosen to have a

1 maximum torque output which is equal to the maximum  
2 torque required by the worst anticipated sea state, that  
3 is a motor which is capable of providing such torque on a  
4 continuous basis. This leads to the use of a motor  
5 having a high inertia, which in turn increases the  
6 response time of the winch.

7  
8 US-A-4,547,857 is one example of a predictive heave  
9 compensation system using either a hydraulic or an  
10 electric winch motor.

11  
12 US-A-4,434,972 discloses a hydraulic hoisting arrangement  
13 in which a winch drum is driven through a gear train and  
14 freewheel arrangement by two hydraulic motors: a high-  
15 torque, low-speed motor for hoisting, and a low-torque,  
16 high-speed motor for compensating.

17  
18 These and other prior art proposals suffer from system  
19 time lags which introduce a phase shift between the sea  
20 surface waveform and the motion of the hoisting drum.

21  
22 The present invention provides a dynamic winch for use in  
23 a heave compensation system, comprising a winch drum and  
24 an electric motor connected to rotate the winch drum; and  
25 in which the electric motor is an AC motor controlled by  
26 a variable speed drive.

27  
28 From another aspect, the invention provides a maritime  
29 reeling system comprising a winch as defined in the  
30 preceding paragraph mounted on a marine structure, and a  
31 sensor arranged to sense a parameter associated with  
32 heave in the vicinity of said structure, said sensor

1 being connected to supply an input signal to said  
2 variable speed drive.

3

4 An embodiment of the invention will now be described, by  
5 way of example only, with reference to the drawings, in  
6 which:

7 Fig 1 illustrates the system response in a typical  
8 prior art heave compensation system, as discussed above;

9 Fig 2 is a schematic side view of a vessel from  
10 which an item is suspended by a winch system;

11 Fig 3 schematically shows idealised wave motion of  
12 the surface of the sea;

13 Fig 4 shows typical actual sea conditions;

14 Fig 5 illustrates one system embodying the present  
15 invention;

16 Fig 6 illustrates the system response of the system  
17 of Fig 5; and

18 Fig 7 is a schematic diagram of the drive  
19 arrangement for the system of Fig 5.

20

21 Fig 2 shows schematically a vessel 10 on the sea surface  
22 12 and supporting a load 14 from a cable 16 by means of a  
23 crane, derrick or overboarding sheave arrangement 18,  
24 controlled by a reeling system (hereinafter termed a  
25 "reeler") 20. The reeler is able to reel in or pay out  
26 the cable 16 in order to raise or lower the load relative  
27 to the vessel 10.

28

29 In particular, the reeler 20 is intended for use with an  
30 umbilical, for deploying, retrieving and storing the  
31 umbilical in a manner which protects the umbilical  
32 against damage. Umbilicals may be complex and expensive  
33 items, incorporating services such as electrical,

1 hydraulic or pneumatic power supplies, signal cables,  
2 fibre optics and the like, and therefore vulnerable to  
3 expensive damage if not handled appropriately.

4  
5 The sea surface 12 will normally have waves moving across  
6 it, causing the vessel 10 to heave as the waves pass  
7 beneath it. Fig 3 shows an idealised profile of the  
8 surface 12, which is sinusoidal, as assumed for example  
9 in standard works such as Lloyds directory of Shipping.  
10 This Directory provides reference data concerning the  
11 amplitude and frequency of waves expected in different  
12 sea states and in different sea areas. In reality, the  
13 motion of the sea surface will rarely be as uniform as  
14 suggested by Fig 3 and may exhibit variations such as  
15 those shown in Fig 4, in which the amplitude and  
16 frequency of the waves each varies with time and  
17 position. Thus, the wave motion may be relatively large  
18 in amplitude and low in frequency, as indicated generally  
19 at 22; or lower in amplitude but still lower in frequency  
20 as indicated at 24; or high in amplitude and high in  
21 frequency as indicated at 26. Many other sea states may  
22 be encountered. In practice the variations encountered  
23 will depend on the sea area being considered, weather  
24 conditions, tidal conditions, and the like, resulting in  
25 the vessel moving in a combination of heave, pitch, yaw  
26 and roll.

27  
28 The present invention seeks to track the heave  
29 substantially without phase shift, thus avoiding the need  
30 for predictive techniques.

31  
32 Fig 5 illustrates a maritime reeling system in accordance  
33 with the present invention. The system 40 has a drum 42



1 rotatably mounted in side cheeks 44 by appropriate  
2 bearings. The drum 42 will carry a cable (not shown) for  
3 paying out or reeling in by rotation of the drum 42 in an  
4 appropriate sense. Cable guides 48 are provided, as will  
5 be described in more detail below, to assist in providing  
6 accurate spooling of the cable onto the drum 42, to  
7 minimise damage to the cable. Power to turn the drum 42  
8 is provided by a motor 50 coupled with the drum by a  
9 drive train indicated generally at 52 at one end of the  
10 drum 42. The drive train 52 may incorporate gearboxes  
11 and the like.

12

13 The motor 50 is an AC motor, of a type well known in  
14 itself. The requirements for the motor in the present  
15 system are discussed in more detail below. The motor 50  
16 receives power from a control circuit 56 which is  
17 preferably remote from the motor 50. The control circuit  
18 56 is arranged, as will be discussed in more detail  
19 below, to supply power to the motor 50 in such a manner  
20 that the motor speed follows an input signal 58. The  
21 input signal 58 is preferably representative of the speed  
22 of the load 14 relative to a fixed frame of reference  
23 (the sea bed), but could alternatively be a function of  
24 the acceleration of the load, the absolute position of  
25 the load, or the tension in the cable 16.

26

27 One suitable arrangement, indicated in Fig. 1, is a  
28 sensor 60 (for example, an ultrasonic sensor) located on  
29 the vessel 12 to measure the instantaneous distance  
30 between the vessel and the sea bed, from which the  
31 instantaneous speed may be derived.

32

1 In the event of the sea surface being entirely flat,  
2 which is most uncommon, no heave compensation will be  
3 required. The input 58 will indicate zero load speed,  
4 and consequently the controller 56 will provide zero  
5 input to the motor 50. Once the sea surface 12 begins to  
6 move, the input 58 will indicate speed of the load 14  
7 relative to the sea bed, and the control circuit 56 will  
8 immediately respond by instructing the motor 50 to turn  
9 in the appropriate direction to cause the system 40 to  
10 pay out or reel in cable in order to negate the heave,  
11 the motor being controlled to attain a target speed  
12 equivalent to the instantaneous speed of the load.

13

14 The nature of the motor 50 and the fact that it is speed  
15 driven allows the control circuit 56 to respond directly  
16 to any change in load speed or position being sensed.  
17 That is to say, the drum 42 can start turning almost  
18 instantly as soon as any change in load speed or position  
19 is sensed. Because of the speed of response, and by  
20 arranging to provide adequate power output from the motor  
21 50 and low inertia within the system, the cable can be  
22 paid out or reeled in sufficiently rapidly to track the  
23 heave, so that the load 14 can be retained at an  
24 accurate, fixed position.

25

26 This speed of response contrasts markedly with the  
27 response characteristics of a predictive system using  
28 hydraulics, pneumatics or a DC electric motor, and allows  
29 the system to track the instantaneous position without  
30 any requirement for prediction, and therefore providing  
31 the ability to respond immediately to any changes in wave  
32 amplitude, frequency or shape. The problems associated  
33 with a predictive system are thereby substantially

1 avoided. The heave compensation provided by a system  
2 according to the present invention can remain in phase  
3 with the sea motion being experienced, at all times, by  
4 virtue of the substantially instantaneous response  
5 achieved by electronic control in conjunction with an AC  
6 motor and low inertia components.

7  
8 Fig 6 shows the system response of the system of Fig 5.  
9 The input signal 34 is a speed signal, and the motor is  
10 driven to have its speed 36 follow the input signal 34.  
11 The motor speed 36 is smooth and substantially in phase  
12 with the input signal 34. The winch will accelerate and  
13 decelerate smoothly and always be in phase with the  
14 motion input. The motion torque curves will always be  
15 out of phase with the speed curve.

16  
17 An AC motor will have a minimum rotation speed below  
18 which operation is not possible or is unpredictable, so  
19 that it is preferable for the control circuit 56 not to  
20 instruct motor movement when the load position is  
21 changing at a rate lower than a predetermined threshold  
22 rate. However, when changing at a very low rate, tension  
23 on the cable will be changing only very slowly and thus  
24 not dangerously for the integrity of the cable. Applying  
25 a threshold in this manner will have the effect of  
26 damping the peaks of the wave motion by not responding to  
27 the wave shape at or close to the peak, but it is  
28 envisaged that by appropriate design or choice of motor  
29 this damping can be reduced to an extent at which cable  
30 damage is avoided. The use of the threshold has the  
31 advantage of preventing the system hunting in the event  
32 of small changes being experienced.

33

1 The drive train to the drum 42 is shown in more detail,  
2 schematically, in Fig 7. As has been described, the  
3 motor 50 is controlled by the control circuit 56, which  
4 is an electrical variable speed drive unit. Suitable  
5 variable speed drive units include the "Midimaster"  
6 vector drive by Siemens and the "ALSPA MV3000" by Alstom  
7  
8 The motor 50 drives a gear box 62 mounted on one side  
9 cheek 44, which in turn drives the outer ring 64B of a  
10 ball race 64, by means of a pinion 66. The outer ring  
11 64B is secured to the drum 42 and co-operates with an  
12 inner ring 64A secured to the side cheek 44, so that  
13 operation of the motor 50, through the gear box 62 and  
14 pinion 66, will cause the drum 42 to rotate within the  
15 stationary side cheeks 44.  
16  
17 In the interests of the speed of response, the design of  
18 the drive train should be chosen to minimise delays in  
19 the response of the system, particularly from inertia and  
20 friction.  
21  
22 The control circuit 56 can be substantially wholly  
23 electrical or electronic, receiving electrical signals  
24 from sensors such as 60, so as to minimise delays in the  
25 system.  
26  
27 The motor 50 should be selected for low inertial  
28 properties. Examples are commercially available, such as  
29 the flux vector drive motors manufactured by Siemendori  
30 or by Siemens. Similarly, the design of gear box 62  
31 should be chosen for low inertial properties and could be  
32 a Cyclo gear box manufactured by Sumitomo, or a compound  
33 gearbox type. The components of the ball race 64 can

1 also be designed for minimally increasing the moment of  
2 inertia of the drum 42, by appropriate choice of  
3 materials, sizes and the like. Reduction of moments of  
4 inertia within the system reduces the overall torque  
5 requirement of the motor 50, thus allowing a low inertia  
6 motor to be used, with further improvement in the  
7 response time of the system. The drive train can also be  
8 designed to reduce backlash, particularly in the gear box  
9 62.

10

11 The choice of the motor 50 will be governed by the  
12 following considerations. In an AC motor the speed and  
13 torque are linked. Maximum torque can be developed at  
14 any speed up to a certain maximum (the synchronous speed)  
15 determined by the physical characteristics of the  
16 machine. Above the synchronous speed, the torque  
17 available will decrease. If the synchronous speed is  
18 high, the motor must be mechanically capable of carrying  
19 the maximum torque at high speed, and this will have an  
20 influence on the inertia of the motor and thus on the  
21 speed of response. With a low synchronous speed  
22 (typically about 1500 rev/min) the inertia of the motor  
23 will be low and its response time fast.

24

25 If the motor is chosen to provide a maximum power  
26 determined by the worst anticipated heave (worst sea  
27 state), the motor will be mechanically large with a high  
28 inertia and poor response time. However, since the sea  
29 waves are approximately sinusoidal, the maximum power is  
30 required only for a fraction of the wave period. In the  
31 remainder of the period a lower power is required. We  
32 have established that in the sea conditions of interest  
33 the required power is lower than 60% of the worst maximum

1 power (worst sea state) for 80% of the wave period.  
2 Therefore, in preferred embodiments of the present  
3 invention the winch motor is chosen to have an  
4 intermittent power rating which can handle the worst sea  
5 state acceleration and power requirement for 20% of the  
6 cycle (typically 60 s in a cycle of 300 s), and to be  
7 capable of handling 60% of the worst sea state power  
8 requirement for the remainder of the time.

9  
10 The worst sea state imposes a requirement for very high  
11 acceleration during part of the wave cycle. In the  
12 preferred forms of the invention, a motor of low  
13 synchronous speed is used. Consequently, during parts of  
14 the wave cycle the motor will operate above its  
15 synchronous speed and torque will tend to fall. When  
16 operating above synchronous speed, the motor can produce  
17 the required torque by increasing its power, which is a  
18 function of speed and torque, above its continuous rated  
19 power.

20  
21 Therefore, the preferred motor is chosen to be capable of  
22 producing 150% of its maximum rated continuous power for  
23 up to 60 s, and of producing 90% of its maximum rated  
24 continuous power for 240 s thereafter. That is, the  
25 preferred motor has a maximum continuous rated power  
26 equal to the substantial part of the worst sea state  
27 power and acceleration requirement. Other combinations of  
28 intermittent and continuous ratings will be possible  
29 within the general concept of using a motor with a  
30 continuous rating less than the worst sea state maximum  
31 power and acceleration requirement. In this way a motor  
32 of minimum inertia is provided.

33

1 Any heave compensation being effected in the manner  
2 described above may be used to maintain the load 14 in a  
3 fixed position, or may be superposed on drum rotation  
4 required for a given deployment or retrieval of the load  
5 14, so that deployment or retrieval can be a steady  
6 operation even with heave of the vessel 10.

7  
8 The reeler 20 is capable of suspending a load on the  
9 surface of the sea without producing any unnecessary  
10 strain on the umbilical used for deploying the suspended  
11 load, because the swell on the sea is substantially  
12 instantaneously compensated by the arrangements  
13 described. Synchronising the umbilical length to the sea  
14 motion in this way is possible even if the vessel 10 is  
15 being driven in the horizontal plane.

16  
17 Referring again to Fig 5, the winch is provided with a  
18 level wind mechanism in which cable being paid out or  
19 reeled in passes through guides 48 in the form of  
20 elongate parallel rollers and other devices mounted at  
21 one end on a shuttle 68. The shuttle 68 is movable along  
22 a threaded shaft 70 parallel to the axis of the drum 42,  
23 the shaft 70 being rotated by an electric motor (not  
24 shown) to drive the shuttle 68 along the shaft 70. The  
25 motor is preferably controlled by the control circuit 56  
26 (or another circuit communicating with the circuit 56)  
27 such that movement of the guides 48 along the drum 42 is  
28 synchronised with rotation of the drum 42 to achieve an  
29 accurate helical laying of the cable 16 on the drum 42.  
30 The same inertia requirement and acceleration apply to  
31 the level wind assembly.

32

1 The control arrangements for rotating the shaft 70  
2 operate to match the speed of rotation of the drum 42  
3 with the speed of movement of the guides 48 along the  
4 shaft 70, at a fixed ratio dependent on the diameter of  
5 the umbilical being reeled. If a different diameter  
6 umbilical is to be used, then a new ratio and speed can  
7 be selected, for which reason it is convenient for the  
8 shaft 70 to be controlled by an electronic control  
9 system, electronic gearbox, or the like, to allow ready  
10 adjustment of the ration being used. In this way, the  
11 co-ordination of the two motor speeds can be highly  
12 sophisticated, such as to change at different points  
13 along the length of the umbilical in the event that the  
14 umbilical diameter is not constant along its length. The  
15 position or speed of the drum 42 can be provided for  
16 control of the shaft 70 by encoders at an appropriate  
17 location within the drive train to the drum 42.

18

19 Accurate helical laying of the umbilical on the drum 42  
20 is important in preventing damage and wear of the  
21 umbilical, particularly by chafing or abrasion.  
22 Consequently, the guides 48 must be positioned with a  
23 response time fast enough to match the response times  
24 with which the drum 42 can be rotated, and this is  
25 facilitated by the use of electronic control of the shaft  
26 70 and by the choice of low inertia components.

27

28 It is apparent from Fig 5 that the arrangements for  
29 driving the drum 42 are located outside the drum, so that  
30 the centre 72 of the drum can be open and substantially  
31 unobstructed. This provides a number of advantages.  
32 First, the open drum centre provides a location for  
33 couplings to the end of the cable 16, such as for power



1 transfer, fibre optic connections, or the like.  
2 Secondly, the open nature of the centre 72 provides for  
3 air or water cooling of the drum 42 from within. This  
4 can be important in practice, particularly when the cable  
5 16 is conducting electrical power to the load 14. Power  
6 being conducted along the cable 16 will tend to give rise  
7 to inductive heating effects due to the coiled nature of  
8 the cable 16 around the drum 42, which can be offset by  
9 cooling via the centre 72.

10

11 It is envisaged that when the cable is being paid out  
12 resistive braking external to the motor 50 or elsewhere  
13 in the drive train can be used to control drum motion,  
14 and also to generate electrical power which can be  
15 provided to the vessel 10 to reduce the mean power  
16 requirement of the winch arrangement or for other  
17 purposes. In addition, the magnetic nature of the motor  
18 allows the drum position to be located almost  
19 instantaneously when stopping, without any bounce.

20

21 The load illustrated in Fig 1 is an item such as a piece  
22 of equipment hanging from the cable 16. Alternatively,  
23 the load could be the weight of a cable being laid on the  
24 seabed, with the heave compensation arrangement used for  
25 shock absorbing. As another alternative, the load could  
26 be the tension in a mooring cable, towing cable or the  
27 like. While the vessel 10 is illustrated as a ship, it  
28 will be apparent that similar problems are experienced  
29 with semi-submersible oil rigs and other floating  
30 structures, and in transferring loads between fixed  
31 structures (such as seabed-located oil rigs) and floating  
32 structures (such as supply vessels). In one application  
33 envisaged for the invention, heave compensation would be

1 provided for a tanker loading from a subsea oil well  
2 installation.

3

4 The apparatus described above may be modified without  
5 departing from the scope of the present invention as  
6 defined in the appended claims. More than one sensor may  
7 be used for detecting the motion to be compensated. For  
8 instance, sensors could be provided on the load, on the  
9 vessel, on the sea surface, or on the seabed.

10

11

12

13

14

15

16

17

18

19

20

1     CLAIMS

2

3     1.   A dynamic winch for use in a heave compensation  
4           system, comprising a winch drum and an electric  
5           motor connected to rotate the winch drum; and in  
6           which the electric motor is an AC motor  
7           controlled by a variable speed drive.

8

9     2.   A winch according to claim 1, in which the motor  
10          has a sufficiently high speed and acceleration  
11          and the winch has a sufficiently low inertia to  
12          follow a speed signal input substantially  
13          instantaneously.

14

15    3.   A winch according to claim 1 or claim 2, in  
16          which the motor is a flux vector drive motor.

17

18    4.   A winch according to any preceding claim, in  
19          which the motor is selected in relation to the  
20          maximum anticipated sea state acceleration and  
21          power requirement to have a continuous power  
22          rating less than the maximum sea state required  
23          power and to be capable of producing the maximum  
24          sea state required power for a fraction of the  
25          anticipated wave sinusoidal cycle.

26

27    5.   A winch according to claim 4, in which the motor  
28          is selected to be capable of producing the  
29          maximum sea state required power for 20% of the  
30          wave cycle and 60% of that power for the

- 1 remainder of the wave cycle when the motor is  
2 running past synchronous speed.  
3
- 4 6. A winch according to claim 5, in which the motor  
5 can produce 150% of its continuous rated power  
6 for 20 s in a 300 s period.  
7
- 8 7. A winch according to any preceding claim, in  
9 which the winch drum is mounted for rotation  
10 between stationary cheeks, and the motor drives  
11 the drum via a gear train secured to the  
12 exterior of one of said cheeks.  
13
- 14 8. A winch according to claim 7, in which the winch  
15 drum has an open centre.  
16
- 17 9. A winch according to any preceding claim,  
18 including a level wind mechanism driven by a  
19 second electric motor synchronised with the  
20 motor which drives the winch drum.  
21
- 22 10. A maritime reeling system comprising a winch in  
23 accordance with any preceding claim mounted on a  
24 marine structure, and a sensor arranged to sense  
25 a parameter associated with heave in the  
26 vicinity of said structure, said sensor being  
27 connected to supply an input signal to said  
28 variable speed drive.  
29

- 1     11. A system according to claim 10, in which said  
2         parameter is the vertical speed of the water  
3         surface or of an object floating on it.  
4
- 5     12. A system according to claim 10, in which said  
6         object is the marine structure on which the  
7         winch is mounted.  
8
- 9     13. A system according to claim 10, in which said  
10        object is the winch load.  
11  
12

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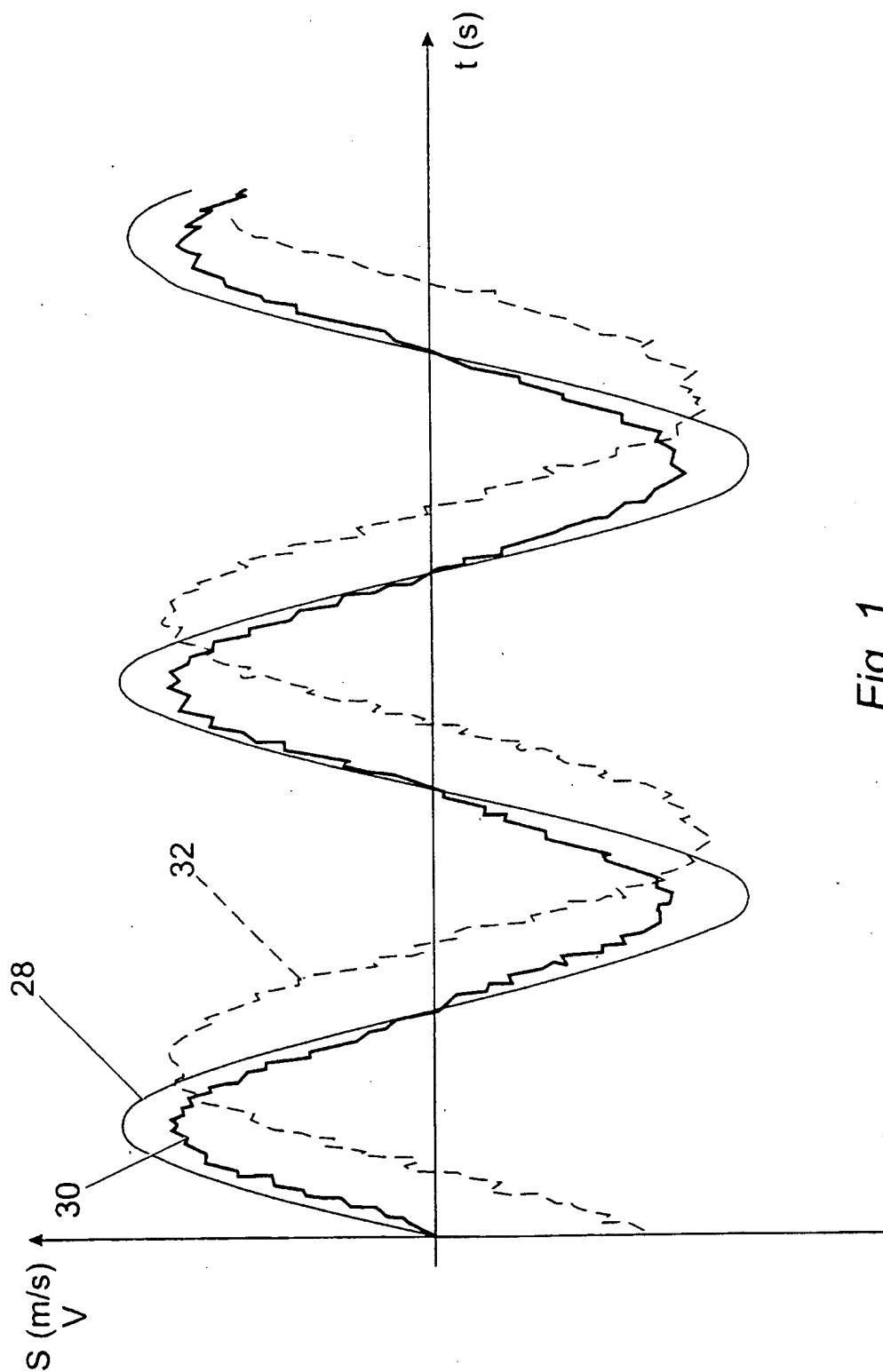


Fig. 1

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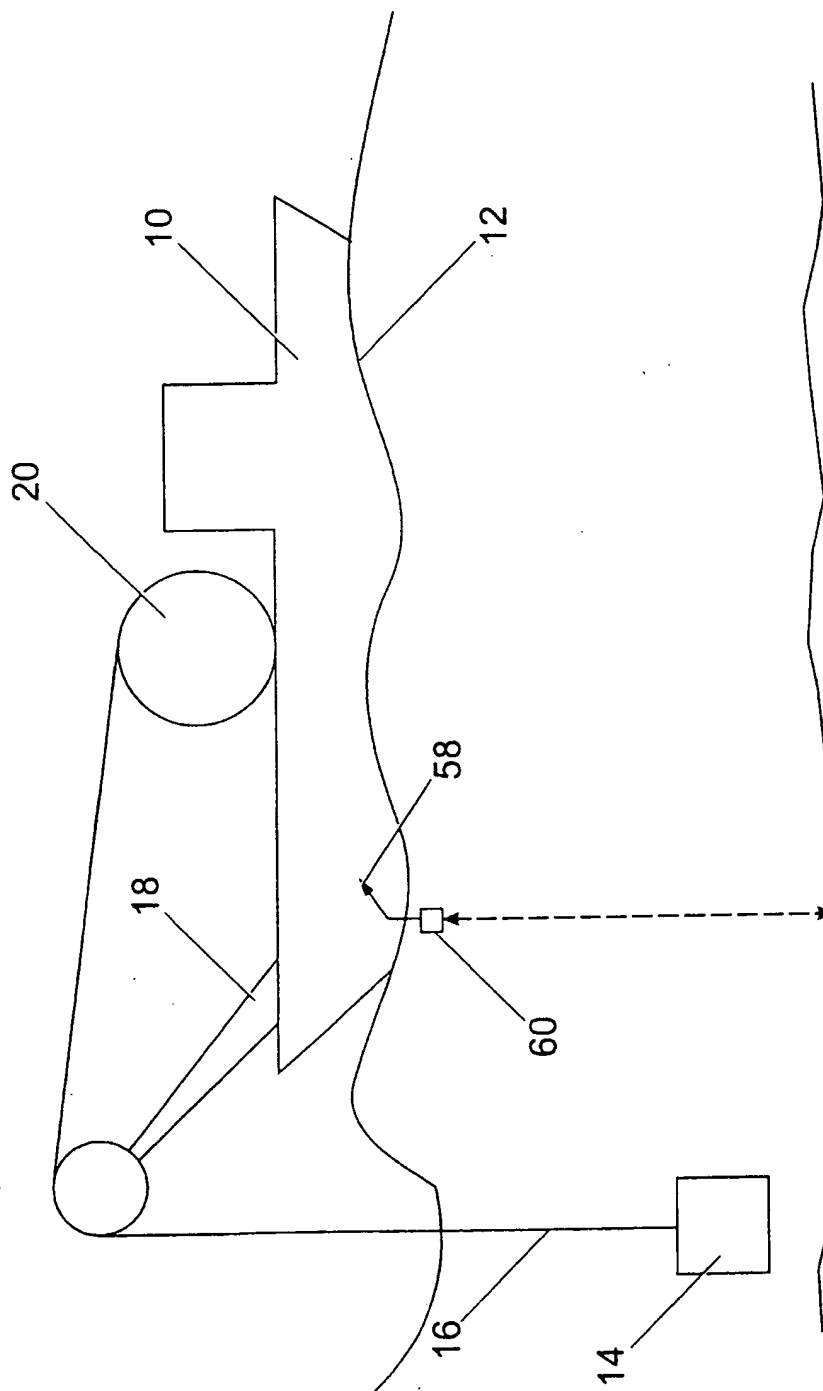
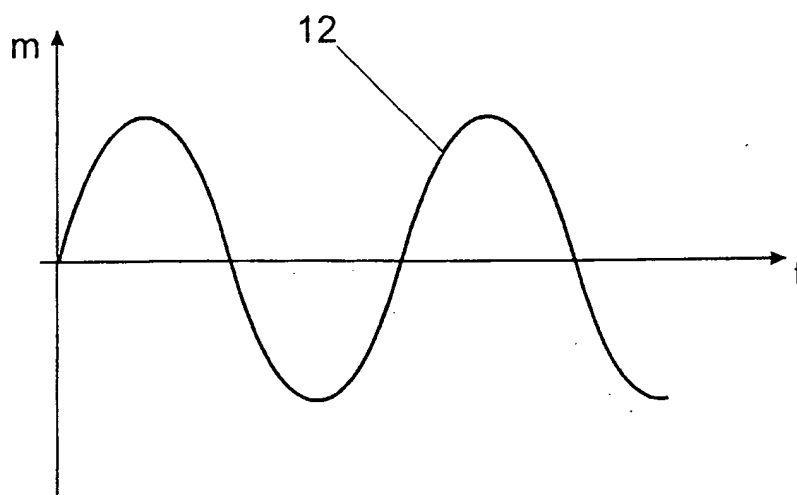
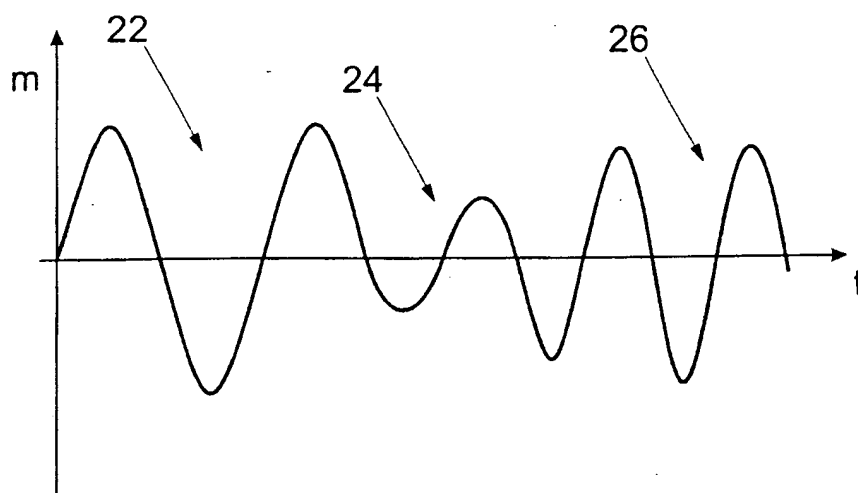


Fig. 2

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*Fig. 3**Fig. 4*



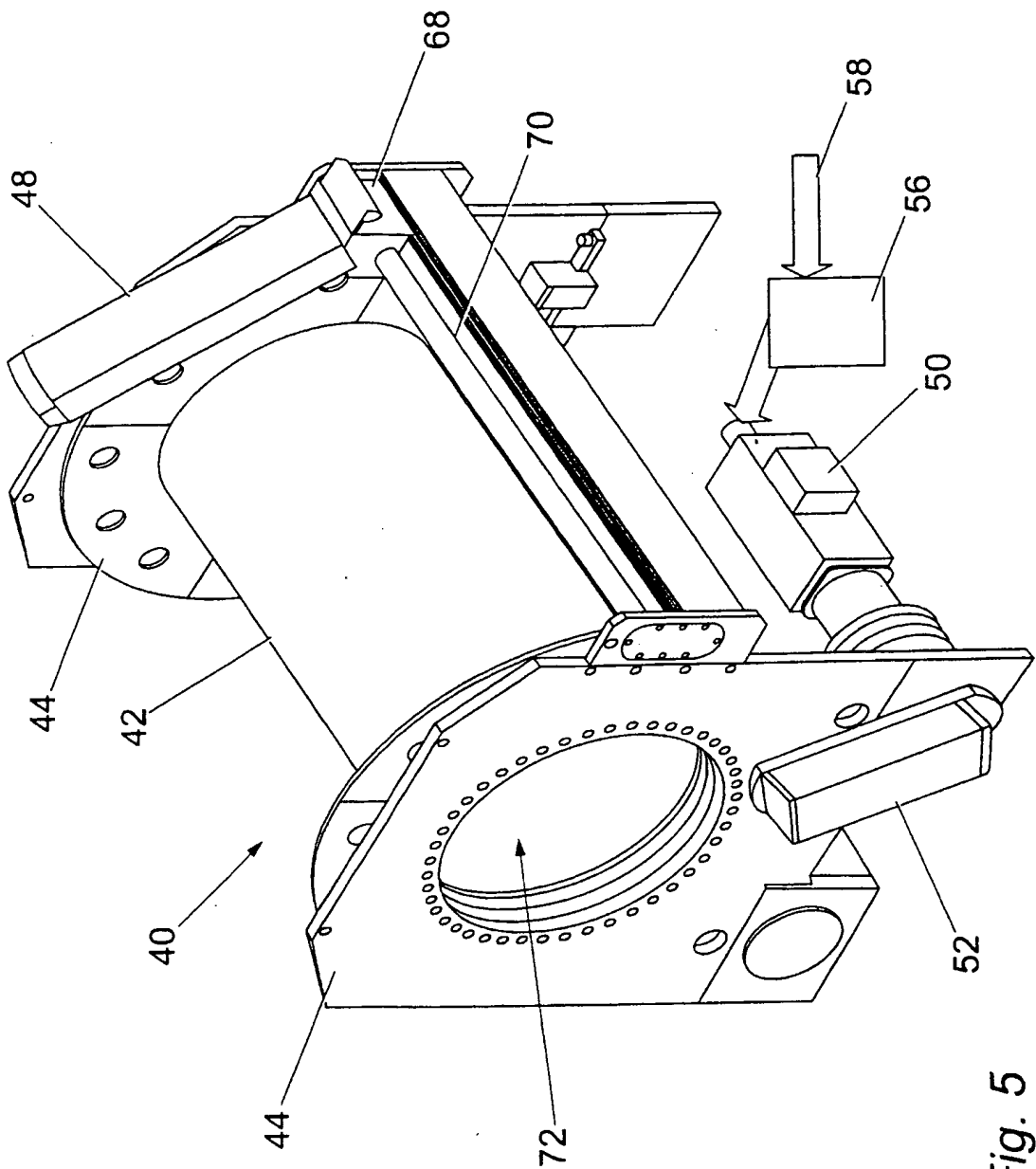


Fig. 5

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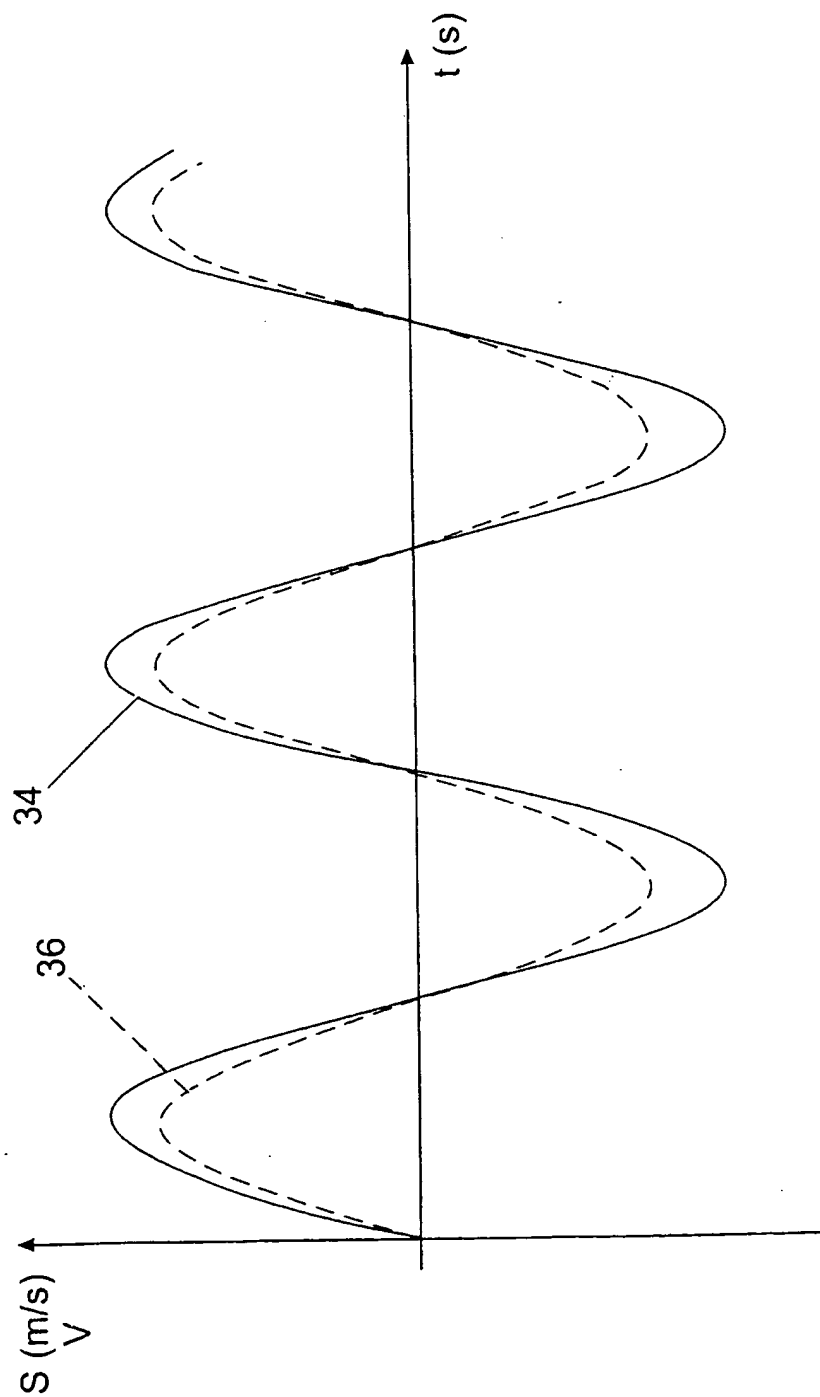
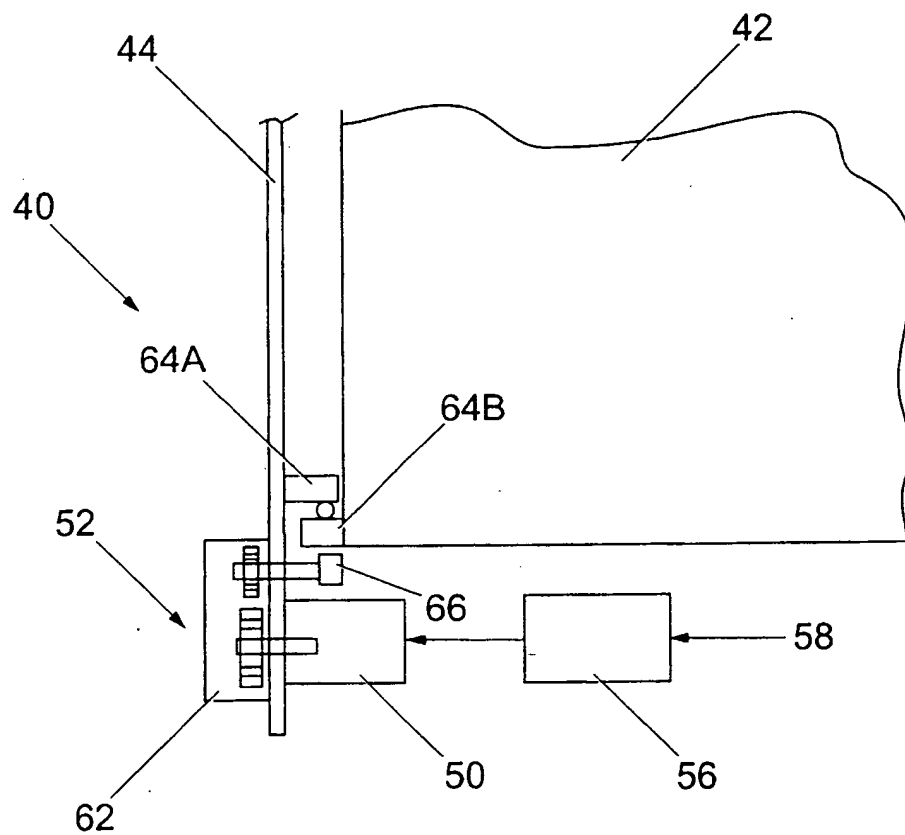


Fig. 6

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*Fig. 7*

# INTERNATIONAL SEARCH REPORT

In ational Application No

PCT/GB 00/04687

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 B66D1/52 B66D1/50 B66D1/38

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B66D H02P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	the whole document	7-13
Y	US 4 736 929 A (MCMORRIS MICHAEL L) 12 April 1988 (1988-04-12) abstract figures 2,3	7,8
Y	DE 38 32 192 A (BROEHL GMBH & CO OHG MASCHF) 27 July 1989 (1989-07-27) abstract figure 1	9
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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15 March 2001

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